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**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

Inventor(s) : Christoph HALUSCHKA et al.  
Serial No. : To Be Assigned  
Filed : Herewith  
For : SHEATHED-ELEMENT GLOW PLUG HAVING AN  
IONIC CURRENT SENSOR AND METHOD FOR  
OPERATING SUCH A SHEATHED-ELEMENT GLOW  
PLUG  
  
Examiner : To Be Assigned  
Art Unit : To Be Assigned

Assistant Commissioner for Patents  
Washington, D.C. 20231

**PRELIMINARY AMENDMENT AND  
37 C.F.R. § 1.125 SUBSTITUTE SPECIFICATION STATEMENT**

S I R:

Kindly amend the above-captioned application before examination, as  
set forth below.

**IN THE SPECIFICATION AND ABSTRACT:**

In accordance with 37 C.F.R. § 1.121(b)(3), a Substitute Specification  
(including the Abstract, but without claims) accompanies this response. It is  
respectfully requested that the Substitute Specification (including Abstract) be  
entered to replace the Specification of record.

**IN THE CLAIMS:**

On the first page of the claims, first line, change "What is claimed is:"  
to --WHAT IS CLAIMED IS:--.

Please cancel, without prejudice, claims 1 to 14 in the underlying PCT  
application.

8L594613771

Please add the following new claims:

--15. (New) A sheathed-element glow plug provided with an ionic-current sensor, comprising:

a housing; and  
a rod-shaped heating element arranged in a concentric bore hole of the housing, the heating element including:  
at least one insulating layer made of an electrically insulating ceramic material,  
a first lead layer made of an electroconductive ceramic material,  
a second lead layer made of the electroconductive ceramic material,  
a bar located at an end of the heating element on a combustion chamber side and made of the electroconductive ceramic material, the first lead layer and the second lead layer being connected via the bar,  
a first electrode for detecting an ionic current, and  
a second electrode for detecting the ionic current, the first electrode and the second electrode being one of embedded in the at least one insulating layer and applied on the at least one insulating layer.

16. (New) The sheathed-element glow plug according to claim 15, wherein the first electrode and the second electrode are made of a metallic material.

17. (New) The sheathed-element glow plug according to claim 15, wherein the first electrode and the second electrode are made of platinum.

18. (New) The sheathed-element glow plug according to claim 15, wherein the first electrode and the second electrode are made of the electroconductive ceramic material.

19. (New) The sheathed-element glow plug according to claim 18, wherein the first electrode and the second electrode are made from a ceramic composite structure that is made of at least two of the compounds  $\text{Al}_2\text{O}_3$ ,  $\text{MoSi}_2$ ,  $\text{Si}_3\text{N}_4$ , and  $\text{Y}_2\text{O}_3$  in accordance with one of a one-step sintering process and a multi-step sintering process.

20. (New) The sheathed-element glow plug according to claim 18, wherein the first electrode and the second electrode are made from a composite precursor ceramic including a matrix and a filler, the matrix including one of a polysiloxane, a polysilsesquioxane, a polysilane, and a polysilazane, doped with one of boron, nitrogen, and aluminum and produced by pyrolysis, the filler being formal from at least one of the compounds  $\text{Al}_2\text{O}_3$ ,  $\text{MoSi}_2$ ,  $\text{SiO}_2$  and  $\text{SiC}$ .

21. (New) The sheathed-element glow plug according to claim 15, further comprising:

- a first electrical connection; and
- a second electrical connection, wherein the first electrical connection and the second electrical connection are arranged at an end of the heating element remote from the combustion chamber, the first electrical connection being connected to an end of the first electrode remote from the combustion chamber, and the second electrical connection being connected to an end of the second electrode remote from the combustion chamber.

22. (New) The sheathed-element glow plug according to claim 15, further comprising:

- a combustion chamber seal, wherein the second lead layer is connected to ground via the housing and the combustion-chamber seal.

23. (New) The sheathed-element glow plug according to claim 15, further comprising:

- a tubular spacer sleeve made of an electrically insulating material and arranged at an end of the heating element remote from the combustion chamber within the concentric bore hole of the housing.

24. (New) The sheathed-element glow plug according to claim 15, wherein the at least one insulating layer, the first lead layer, the bar, and the second lead layer are made from a ceramic composite structure that is made of at least two of the compounds  $\text{Al}_2\text{O}_3$ ,  $\text{MoSi}_2$ ,  $\text{Si}_3\text{N}_4$ , and  $\text{Y}_2\text{O}_3$  in accordance with one of a one-step sintering process and a multi-step sintering process.

25. (New) The sheathed-element glow plug according to claim 15, wherein the at least one insulating layer, the first lead layer, the bar, and the second lead layer are made from a composite precursor ceramic including a matrix and a filler, the matrix including one of a polysiloxane, a polysilsesquioxane, a polysilane, and a polysilazane, the matrix doped with one or boron, nitrogen, and aluminum and produced by pyrolysis, the filler made from at least one of the compounds  $\text{Al}_2\text{O}_3$ ,  $\text{MoSi}_2$ ,  $\text{SiO}_2$ , and  $\text{SiC}$ .

26. (New) A method for operating a sheathed-element glow plug having an ionic-current sensor, comprising:

applying an electrical voltage to a first lead layer and a second lead layer during a glow phase; and

after the glow phase ends, applying the electrical voltage to a first electrode for detecting an ionic current and to a second electrode for detecting the ionic current.

27. (New) The method according to claim 26, wherein the electrical voltage applied to the first electrode and the electrical voltage applied to the second electrode have a same potential.

28. (New) The method according to claim 26, wherein the electrical voltage applied to the first electrode and the electrical voltage applied to the second electrode have a different potential.

29. (New) A method for operating a sheathed-element glow plug having an ionic-current sensor, comprising:

during a glow phase, applying an electrical voltage to a first lead layer, a second lead layer, a first electrode for detecting an ionic current, and a second electrode for detecting the ionic current.

30. (New) The method according to claim 29, wherein the electrical voltage applied to the first electrode and the electrical voltage applied to the second electrode have a same potential.

31. (New) The method according to claim 29, wherein the electrical voltage applied to the first electrode and the electrical voltage applied to the second electrode have a different potential --.

#### **REMARKS**

This Preliminary Amendment cancels, without prejudice, claims 1 to 14 in the underlying PCT Application No. PCT/DE01/01472. This Preliminary Amendment adds new claims 15 to 31. The new claims, inter alia, conform the claims to U.S. Patent and Trademark Office rules and do not add new matter to the application.

In accordance with 37 C.F.R. § 1.121(b)(3), the Substitute Specification (including the Abstract, but without the claims) contains no new matter. The amendments reflected in the Substitute Specification (including Abstract) are to conform the Specification and Abstract to U.S. Patent and Trademark Office rules or to correct informalities. As required by 37 C.F.R. §§ 1.121(b)(3)(iii) and 1.125(b)(2), a Marked-Up Version of the Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. Approval and entry of the Substitute Specification (including Abstract) are respectfully requested.

The underlying PCT Application No. PCT/DE01/01472 includes an International Search Report, dated October 15, 2001, a copy of which is included.

It is respectfully submitted that the subject matter of the present application is new, non-obvious, and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully submitted,

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SHEATHED-ELEMENT GLOW PLUG HAVING AN IONIC CURRENT  
SENSOR AND METHOD FOR OPERATING SUCH A SHEATHED-  
ELEMENT  
GLOW PLUG

FIELD OF THE INVENTION

The present invention relates to a ceramic sheathed-element glow plug for a diesel engine having an ionic-current sensor.

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BACKGROUND INFORMATION

German Published Patent Application No. 34 28 371 describes a ceramic sheathed-element glow plug that includes a ceramic heating element. The ceramic heating element bears an electrode made of a metallic material which is used to determine the electric conductivity of the ionized gas present in the combustion chamber of the internal combustion engine. In this case, the combustion chamber wall is used as the second electrode.

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Furthermore, sheathed-element glow plugs are known which have a housing in which a rod-shaped heating element is disposed in a concentric bore hole. The heating element is made of at least one insulating layer, as well as a first and a second lead layer, the first and the second lead layers connected via a bar at the tip of the heating element on the combustion chamber side. The insulating layer is made of electrically insulating ceramic material, and the first and second lead layers, as well as the bar, are made of electroconductive ceramic material.

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SUMMARY OF THE INVENTION

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The ceramic sheathed-element glow plug of the present invention with ionic-current sensor has an advantage that the sheathed-element glow plug

with ionic-current sensor has a very simple design and is inexpensive to manufacture.

It is possible to achieve a design of a sheathed-element glow plug if the glow operation and the ionic-current measurement are carried out simultaneously. The electrode for detecting ionic current may be led up to the end of the heating element on the combustion chamber side. The ionic current may be detected in a region of the combustion chamber where the combustion processes takes place in the combustion chamber. It is also illustrated to design two electrodes to detect ionic current in such a way that the ionic current flows from one electrode to the other electrode, and thus only crosses a region of special interest for the ionic-current measurement. It is shown to use the ceramic composite structure described below for the various heating-element layers, where conductivity and expansion coefficients may be adapted very well. This also applies for the precursor composites described below.

In the method for operating a sheathed-element glow plug having ionic-current measurement, the ionic-current detection may be provided during the glowing of the heating element, since it is of interest to detect the combustion process during the start phase of the internal combustion engine.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a longitudinal sectional view of a sheathed-element glow plug of the present invention with ionic-current sensor.

Figure 2 is a schematic longitudinal sectional view through the combustion-chamber-side end of a sheathed-element glow plug of the present invention with ionic-current sensor.



Figure 3a shows a first schematic longitudinal sectional view through the heating element of a sheathed-element glow plug of the present invention with ionic-current sensor.

5 Figure 3b shows a second schematic longitudinal sectional view through the heating element of a sheathed-element glow plug of the present invention with ionic-current sensor.

10 Figure 4 shows a schematic cross-sectional view through a heating element of a sheathed-element glow plug of the present invention with ionic-current sensor.

#### DETAILED DESCRIPTION

15 Figure 1 illustrates a sheathed-element glow plug of the present invention schematically in longitudinal section. A tubular housing 3, which may be made of metallic material, contains a heating element 5 in its concentric bore hole at the end on the combustion chamber side. Heating element 5 may be made of ceramic material. Heating element 5 may have a first lead layer 7 and a  
20 second lead layer 9, first lead layer 7 and second lead layer 9 made of electroconductive ceramic material. At end 6 of heating element 5 remote from the combustion chamber, first lead layer 7 and second lead layer 9 are connected by a bar 8. In the example embodiment illustrated, the bar 8 may be made of electroconductive ceramic material. First lead layer 7 and second  
25 lead layer 9 may be separated from each other by an insulating layer 11. Insulating layer 11 may be made of electrically insulating ceramic material. The interior of housing 3 is sealed in the direction of the combustion chamber by a combustion-chamber seal 13 surrounding heating element 5 in a ring shape. At the end of heating element 5 remote from the combustion chamber,  
30 first lead layer 7 is connected to a third connection 37. In the direction of the end of the sheathed-element glow plug remote from the combustion chamber, this third connection 37 is connected to terminal stud 19. At its end remote from the combustion chamber, second lead layer 9 has a contact area 12 via

which second lead layer 9 is electrically connected to housing 3 by way of electroconductive combustion-chamber seal 13. Housing 3 is connected to ground. In an example embodiment, contact area 12 may be constructed in such a way that in this region, the electrically insulating glass coating  
5 surrounding the end of heating element 5 remote from the combustion chamber is interrupted, and consequently an electrical contact is produced with combustion-chamber seal 13. In another example embodiment, contact area 12 is provided with a metallic coating.

Terminal stud 19 is set apart from the end of heating element 5 remote from the combustion chamber by a ceramic spacer sleeve 27 disposed in the concentric bore hole of housing 3. In the direction of the end remote from the combustion chamber, terminal stud 19 is led through a clamping sleeve 29 and a metal sleeve 31. At the end of the sheathed-element glow plug remote  
10 from the combustion chamber, a circular connector 25, which effects the electrical connection, is mounted on terminal stud 19. The end of the concentric bore hole of housing 3, remote from the combustion chamber, is sealed and electrically insulated by a tubing ring 21 and an insulating disk 23.

The present invention is also illustrated in Figure 2. Only the end of a sheathed-element glow plug according to the present invention on the combustion chamber side is illustrated schematically in longitudinal section. Compared to Figure 1, heating element 5 is intersected in a plane transverse to the sectional plane of Figure 1. Here, only insulating layer 11 is visible.  
20 Within insulating layer 11 two electrodes 33 and 33' are placed for detecting ionic current which are broadened at end 6 of heating element 5 on the combustion chamber side. In a further example embodiment, electrodes 33 and 33' may also be applied outside on the insulating layer. At the end of heating element 5 remote from the combustion chamber, first electrode 33 for  
25 detecting ionic current is connected to a first connection 15. Second electrode 33' for detecting ionic current is likewise connected at the end of heating element 5 remote from the combustion chamber to a second connection 17. First connection 15 and second connection 17 are passed through terminal  
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stud 19 to the end of the sheathed-element glow plug remote from the combustion chamber. As previously mentioned, first lead layer 7 is connected to terminal stud 19 with the aid of a third connection 37.

5 The arrangement of the various layers of heating element 5 together with the associated connections are illustrated again with reference to Figure 3. Figure 3a illustrates a heating element 5 in longitudinal section. First electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current are disposed in insulating layer 11. At the end of heating element 5 remote from the combustion chamber, first electrode 33 for detecting ionic current is connected to first connection 15, and second electrode 33' for detecting ionic current is connected to second connection 17. In addition, at the end of heating element 5 on the combustion chamber side, bar 8 is discernible which connects first lead layer 7 and second lead layer 9 to one another.

15 Figure 3b shows heating element 5 which is intersected in a plane transverse to the plane in which heating element 5, which was illustrated in Figure 3a, is intersected. First lead layer 7 and second lead layer 9 are interconnected via bar 8 at end 6 of heating element 5 remote from the combustion chamber. Third connection 37 is connected to first lead layer 7 at the end of heating element 5 remote from the combustion chamber.

20 Figure 4 shows a cross-section through heating element 5 at the end remote from the combustion chamber. First lead layer 7 is separated from second lead layer 9 by insulating layer 11. Arranged within insulating layer 11 is first connection 15 which is connected to first electrode 33 for detecting ionic current. Likewise arranged within insulating layer 11 is second connection 17 which is connected to second electrode 33' for detecting ionic current. Third connection 37 is disposed within first lead layer 7. To better accommodate and insulate first and second electrodes 33, 33' for detecting ionic current, the insulating layer is broadened in the region in which these electrodes are arranged.

In a first example embodiment, the sheathed-element glow plug may be operated in such a way that during the start of the internal combustion engine, the sheathed-element glow plug is initially operated in heating mode. During the glow phase, a positive voltage with respect to ground is applied to third connection 37, so that a current flows across first lead layer 7, bar 8 and second lead layer 9. Due to the electrical resistance on this path, the temperature of the heating element rises, and the combustion chamber, into which the end of the sheathed-element glow plug on the combustion chamber side extends, is heated. After ending the glow phase, a voltage potential is applied to first connection 15 and second connection 17, so that first electrode 33 and second electrode 33' are used as electrodes for measuring ionic current. If the combustion chamber is ionized due to the presence of ions, then an ionic current may flow from electrodes 33, 33' for detecting ionic current to the combustion-chamber wall which is grounded. In this example embodiment, first electrode 33 for detecting ionic current and the second electrode for detecting ionic current act as electrodes at the same potential in parallel.

In a further example embodiment, a different voltage potential may be applied to first electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current so that an ionic current flows between first electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current.

In another example embodiment, the glow operation and the detection of ionic current may be carried out simultaneously by the sheathed-element glow plug. The voltage for the glow operation and for detecting ionic current is applied simultaneously to third connection 37 and to first and second connections 15, 17, respectively. The voltage potentials may be selected such that first electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current are at the same or different potential, as described above, the ionic current flows via the ionized combustion chamber to the combustion chamber wall, or from first electrode 33 for detecting ionic

current via the ionized combustion chamber to second electrode 33' for detecting ionic current.

In a first example embodiment, the materials of first lead layer 7, bar 8, second lead layer 9, insulating layer 11 and electrode 33 for detecting ionic current, as well as second electrode 33' for detecting ionic current may be made of ceramic material. This ensures that the thermal expansion coefficients of the materials scarcely differ, thus guaranteeing the endurance strength of heating element 5. The material of first lead layer 7, bar 8 and second lead layer 9 is selected such that the resistance of these layers is less than the resistance of insulating layer 11. The resistance of first electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current is less than the resistance of insulating layer 11.

In a further example embodiment, first electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current may also be made of metallic material, e.g. platinum.

In another example embodiment, first lead layer 7, bar 8 and second lead layer 9, insulating layer 11 and possibly first electrode 33 and second electrode 33' are made of ceramic composite structures which contain at least two of the compounds  $Al_2O_3$ ,  $MoSi_2$ ,  $Si_3N_4$  and  $Y_2O_3$ . These composite structures are obtainable by a one-step or multi-step sintering process. The specific resistance of the layers may preferably be determined by the  $MoSi_2$  content and/or the grain size of  $MoSi_2$ ; the  $MoSi_2$  content of first lead layer 7, of bar 8 and of second lead layer 9, as well as of first and second electrodes 33, 33' for detecting ionic current may be higher than the  $MoSi_2$  content of insulating layer 11.

In a further example embodiment, first lead layer 7, bar 8, second lead layer 9, insulating layer 11 and possibly first electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current are made of a composite precursor ceramic having different portions of fillers. The matrix of this

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## ABSTRACT

A sheathed-element glow plug having an ionic-current sensor, as well as a method for operating a sheathed-element glow plug having an ionic-current sensor are described, the sheathed-element glow plug having a housing and a rod-shaped heating element arranged in a concentric bore hole of the housing. The heating element has at least one insulating layer as well as a first lead layer and a second lead layer, the first lead layer and the second lead layer being connected via a bar at the end of the heating element on the combustion chamber side, the first and second lead layers and the bar being made of electroconductive ceramic material, and the insulating layer being made of electrically insulating ceramic material. The heating element has a first electrode for detecting ionic current and a second electrode for detecting ionic current which are embedded in the insulating layer or applied on the insulating layer.

SHEATHED-ELEMENT GLOW PLUG HAVING AN IONIC CURRENT  
SENSOR AND METHOD FOR OPERATING SUCH A  
SHEATHED-ELEMENT  
GLOW PLUG

[Background Information] FIELD OF THE INVENTION

The present invention [is based on] relates to a ceramic sheathed-element  
glow plug for a diesel [engines] engine having an ionic-current sensor  
[according to the species defined in the first independent claim. The German  
laid open print 34 28 371 has already described].

BACKGROUND INFORMATION

German Published Patent Application No. 34 28 371 describes a ceramic  
sheathed-element glow [plugs which have] plug that includes a ceramic  
heating element. The ceramic heating element bears an electrode made of a  
metallic material which is used to determine the electric conductivity of the  
ionized gas present in the combustion chamber of the internal combustion  
engine. In this case, the combustion chamber wall is used as the second  
electrode.

Furthermore, sheathed-element glow plugs are known which have a housing  
in which a rod-shaped heating element is disposed in a concentric bore hole.  
The heating element is made of at least one insulating layer, as well as a first  
and a second lead layer, the first and the second lead layers [being]  
connected via a bar at the tip of the heating element on the combustion  
chamber side. The insulating layer is made of electrically insulating ceramic  
material, and the first and second lead layers, as well as the bar, are made of  
electroconductive ceramic material.

[Summary of the Invention] SUMMARY OF THE INVENTION



In the method for operating a sheathed-element glow plug having ionic-current measurement, [it is particularly advantageous to provide] the ionic-current detection may be provided during the glowing of the heating element, since it is of interest to detect the combustion process during the start phase of the internal combustion engine[, as well.].

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element 5 [has] may have a first lead layer 7 and a second lead layer 9, first lead layer 7 and second lead layer 9 [being] made of electroconductive ceramic material. At end 6 of heating element [3] 5 remote from the combustion chamber, first lead layer 7 and second lead layer 9 are connected by a bar 8 [likewise]. In the example embodiment illustrated, the bar 8 may be made of electroconductive ceramic material. First lead layer 7 and second lead layer 9 [are] may be separated from each other by an insulating layer 11. Insulating layer 11 [is] may be made of electrically insulating ceramic material. The interior of housing 3 is sealed in the direction of the combustion chamber by a combustion-chamber seal 13 surrounding heating element 5 in a ring shape. At the end of heating element 5 remote from the combustion chamber, first lead layer 7 is connected to a third connection 37. In the direction of the end of the sheathed-element glow plug remote from the combustion chamber, this third connection 37 is [in turn] connected to terminal stud 19. At its end remote from the combustion chamber, second lead layer 9 has a contact area 12 via which second lead layer 9 is electrically connected to housing 3 by way of electroconductive combustion-chamber seal 13. Housing 3 is connected to ground. In [one preferred exemplary] an example embodiment, contact area 12 may be constructed in such a way that in this region, the electrically insulating glass coating surrounding the end of heating element 5 remote from the combustion chamber is interrupted, and consequently an electrical contact is produced with combustion-chamber seal 13. In [one particularly preferred exemplary] another example embodiment, contact area 12 is provided with a metallic coating.

Terminal stud 19 is set apart from the end of heating element 5 remote from the combustion chamber by a ceramic spacer sleeve 27 disposed in the concentric bore hole of housing 3. In the direction of the end remote from the combustion chamber, terminal stud 19 is led through a clamping sleeve 29 and a metal sleeve 31. At the end of the sheathed-element glow plug remote from the combustion chamber, a circular connector 25, which effects the electrical connection, is mounted on terminal stud 19. The end of the

concentric bore hole of housing 3, remote from the combustion chamber, is sealed and electrically insulated by a tubing ring 21 and an insulating disk 23.

The present invention is [clarified more precisely once again with reference to] also illustrated in Figure 2. Only the end of a sheathed-element glow plug according to the present invention on the combustion chamber side is [shown] illustrated schematically in longitudinal section. Compared to Figure 1, heating element 5 is intersected in a plane transverse to the sectional plane of Figure 1. Here, only insulating layer 11 is visible. [Running within] Within insulating layer 11 [are] two electrodes 33 and 33' are placed for detecting ionic current which are broadened at end 6 of heating element 5 on the combustion chamber side. In a further [exemplary] example embodiment, electrodes 33 and 33' may also be applied outside on the insulating layer. At the end of heating element 5 remote from the combustion chamber, first electrode 33 for detecting ionic current is connected to a first connection 15. Second electrode 33' for detecting ionic current is likewise connected at the end of heating element 5 remote from the combustion chamber to a second connection 17. First connection 15 and second connection 17 are passed through terminal stud 19 to the end of the sheathed-element glow plug remote from the combustion chamber. As [already] previously mentioned, first lead layer 7 is connected to terminal stud 19 with the aid of a third connection 37.

The arrangement of the various layers of heating element 5 together with the associated connections are [shown] illustrated again with reference to Figure 3. Figure 3a [ ] shows] illustrates a heating element 5 in longitudinal section. First electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current are disposed in insulating layer 11. At the end of heating element 5 remote from the combustion chamber, first electrode 33 for detecting ionic current is connected to first connection 15, and second electrode 33' for detecting ionic current is connected to second connection 17. In addition, at the end of heating element 5 on the combustion chamber

side, bar 8 is discernible which connects first lead layer 7 and second lead layer 9 to one another.

Figure 3b[] shows heating element 5 which is intersected in a plane transverse to the plane in which heating element 5, which was [shown] illustrated in Figure 3a[]], is intersected. [Recognizable here are first] First lead layer 7 and second lead layer 9 [which] are interconnected via bar 8 at end 6 of heating element 5 remote from the combustion chamber. Third connection 37 is connected to first lead layer 7 at the end of heating element 5 remote from the combustion chamber.

[To better clarify the invention,] Figure 4 shows a cross-section through heating element 5 at the end remote from the combustion chamber. [It is discernible that first] First lead layer 7 is separated from second lead layer 9 by insulating layer 11. Arranged within insulating layer 11 is first connection 15 which is connected to first electrode 33 for detecting ionic current. Likewise arranged within insulating layer 11 is second connection 17 which is connected to second electrode 33' for detecting ionic current. [Furthermore, third] Third connection 37 is disposed within first lead layer 7. [It can be seen that, to] To better accommodate and insulate first and second electrodes 33, 33' for detecting ionic current, the insulating layer is broadened in the region in which these electrodes are arranged.

In a first [exemplary] example embodiment, the sheathed-element glow plug may be operated in such a way that during the start of the internal combustion engine, the sheathed-element glow plug is initially operated in heating mode. [This means that during] During the glow phase, a positive voltage with respect to ground is applied to third connection 37, so that a current flows across first lead layer 7, bar 8 and second lead layer 9. Due to the electrical resistance on this path, the temperature of the heating element rises, and the combustion chamber, into which the end of the sheathed-element glow plug on the combustion chamber side extends, is heated. After ending the glow phase, a voltage potential is applied to first

connection 15 and second connection 17, so that first electrode 33 and second electrode 33' are used as electrodes for measuring ionic current. If the combustion chamber is ionized due to the presence of ions, then an ionic current [can] may flow from electrodes 33, 33' for detecting ionic current to the combustion-chamber wall which is grounded. In this [exemplary] example embodiment, first electrode 33 for detecting ionic current and the second electrode for detecting ionic current act as electrodes at the same potential in parallel.

In a further [exemplary] example embodiment, [it is also possible to apply] a different voltage potential may be applied to first electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current[,], so that an ionic current flows between first electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current.

In another [exemplary] example embodiment, the glow operation and the detection of ionic current may be carried out simultaneously by the sheathed-element glow plug. [To that end, in each case the] The voltage [necessary] for the glow operation and for detecting ionic current is applied simultaneously to third connection 37 and to first and second connections 15, 17, respectively. [In this context, the] The voltage potentials may be selected such that first electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current are at the same or different potential, [that is to say,] as described above, the ionic current flows via the ionized combustion chamber to the combustion chamber wall, or from first electrode 33 for detecting ionic current via the ionized combustion chamber to second electrode 33' for detecting ionic current.

In a first [exemplary] example embodiment, the materials of first lead layer 7, bar 8, second lead layer 9, insulating layer 11 and electrode 33 for detecting ionic current, as well as second electrode 33' for detecting ionic current [should] may be made of ceramic material. This ensures that the thermal expansion coefficients of the materials scarcely differ, thus guaranteeing the

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second electrodes 33, 33' for detecting ionic current [is preferably] may be set higher than the  $\text{MoSi}_2$  content of insulating layer 11. In the [exemplary] example embodiments indicated above, the compositions of first lead layer 7, bar 8, second lead layer 9, insulating layer 11 and possibly of first electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current are selected such that their thermal expansion coefficients and the shrinkages occurring during the sintering and pyrolysis processes are identical, so that no cracks develop in heating element 5.



[What is claimed is:

1. A sheathed-element glow plug with ionic-current sensor, comprising a housing (3) and a rod-shaped heating element (5) arranged in a concentric bore hole of the housing, the heating element (5) having at least one insulating layer (11) as well as a first lead layer (7) and a second lead layer (9), the first lead layer (7) and the second lead layer (9) being connected via a bar (8) at end (6) of the heating element (5) on the combustion chamber side, the first and second lead layers (7, 9) and the bar (8) being made of electroconductive ceramic material, and the insulating layer (11) being made of electrically insulating ceramic material, wherein the heating element (5) has a first electrode (33) for detecting ionic current and a second electrode (33') for detecting ionic current which are embedded in the insulating layer (11) or are applied on the insulating layer (11).

2. The sheathed-element glow plug as recited in Claim 1, wherein the first electrode (33) for detecting ionic current and the second electrode (33') for detecting ionic current are made of metallic material, preferably platinum.

3. The sheathed-element glow plug as recited in Claim 1, wherein the first electrode (33) for detecting ionic current and the second electrode (33') for detecting ionic current are made of electroconductive ceramic material.

4. The sheathed-element glow plug as recited in Claim 1, wherein a first electrical connection (15) and a second electrical connection (17) are provided at the end of the heating element (6) remote from the combustion chamber, the first electrical connection (15) being connected to the end, remote from the combustion chamber, of the first electrode (33) for detecting ionic current, and the second electrical connection (17) being connected to the end, remote from the combustion chamber, of the second electrode (33') for detecting ionic current.

5. The sheathed-element glow plug as recited in Claim 1, wherein the second lead layer (9) is connected to ground via the housing (3) and combustion-chamber seal (13).

6. The sheathed-element glow plug as recited in Claim 1, wherein at the end of the heating element (6) remote from the combustion chamber, a tubular spacer sleeve (27) made of electrically insulating material is arranged within the concentric bore hole of the housing (3).

7. The sheathed-element glow plug as recited in Claim 1, wherein the insulating layer (11), the first lead layer (7), the bar (8) and the second lead layer (9) are made of ceramic composite structures which are obtainable from at least two of the compounds A1203, MoSi2, Si3N4 and Y2O3 using a one-step or multi-step sintering process.

8. The sheathed-element glow plug as recited in Claim 1, wherein the insulating layer (11), the first lead layer (7), the bar (8) and the second lead layer (9) are made of a composite precursor ceramic, the matrix material including polysiloxanes, polysilsesquioxanes, polysilanes or polysilazanes which may be doped with boron, nitrogen or aluminum and which were produced by pyrolysis, the filler being formed from at least one of the compounds A1203, MoSi2, SiO2 and SiC.

9. The sheathed-element glow plug as recited in Claim 3, wherein the first electrode (33) for detecting ionic current and the second electrode (33') for detecting ionic current are made of ceramic composite structures which are obtainable from at least two of the compounds A1203, MoSi2, Si3N4 and Y2O3 using a one-step or multi-step sintering process.

10. The sheathed-element glow plug as recited in Claim 3, wherein the first electrode (33) for detecting ionic current and the second electrode (33') for detecting ionic current are made of a composite precursor ceramic, the matrix material including polysiloxanes, polysilsesquioxanes, polysilanes or

polysilazanes which may be doped with boron, nitrogen or aluminum and which were produced by pyrolysis, the filler being formed from at least one of the compounds A1203, MoSi2, SiO2 and SiC.

11. A method for operating a sheathed-element glow plug having an ionic-current sensor as recited in Claim 1, wherein during a glow phase, an electrical voltage is applied merely to the first and the second lead layers (7, 9), and after ending the glow phase, an electrical voltage is applied merely to the first electrode (33) for detecting ionic current and to the second electrode (33') for detecting ionic current.

12. A method for operating a sheathed-element glow plug having an ionic-current sensor as recited in Claim 1, wherein during the glow phase, an electrical voltage is applied both to the first and the second lead layers (7, 9), as well as to the first electrode (33) for detecting ionic current and to the second electrode (33') for detecting ionic current.

13. The method as recited in one of Claims 11 or 12, wherein a voltage having the same potential is applied to the first electrode (33) for detecting ionic current and to the second electrode (33') for detecting ionic current.

14. The method as recited in one of Claims 11 or 12, wherein a voltage having different potential is applied to the first electrode (33) for detecting ionic current and to the second electrode (33') for detecting ionic current.

Abstract ABSTRACT

A sheathed-element glow plug having an ionic-current sensor, as well as a method for operating a sheathed-element glow plug having an ionic-current sensor are described, the sheathed-element glow plug having a housing [(3)] and a rod-shaped heating element [(5)] arranged in a concentric bore hole of the housing. The heating element [(5)] has at least one insulating layer [(11)] as well as a first lead layer [(7)] and a second lead layer[(9)], the first lead layer [(7)] and the second lead layer [(9)] being connected via a bar [(8)] at the end [(6)] of the heating element [(5)] on the combustion chamber side, the first and second lead layers [(7, 9)] and the bar [(8)] being made of electroconductive ceramic material, and the insulating layer [(11)] being made of electrically insulating ceramic material. The heating element [(5)] has a first electrode [(33)] for detecting ionic current and a second electrode [(33')] for detecting ionic current which are embedded in the insulating layer [(11)] or [are] applied on the insulating layer[(11)].